Session 2
Key Processes Critical to Precipitation Biases

Climate models
(~50 - 100 km)

Weather models
(~10 km)

Global Storm-Resolving
models (GSRM)
(~3 km)

Sub-grid processes (CRM,
LES, DNS, etc.)
(~< 1 km)

1. Processes/models: Conventional Parameterizations

2. Processes/models: ML-based convective
parameterizations

4. What about shallow convection, PBL and
microphysics (aerosols)?

3. Phenomena/observations: Organized
convection (MCS, convective-large scale
interactions)

1. Processes/Models: Conventional Parameterizations

- At 50-km, climate models can capture some gross features of extreme events (TC, AR and tropical MCS). But, they still struggle with simulating intensity, and mid-latitude land MCS (such as those over summertime CONUS) and the associated diurnal cycle of precipitation.
- The diurnal cycle of land precipitation is much improved in 13-km weather models.
- Approach 1: Make convective parameterizations as non-intrusive as possible, and let the resolved scale do as much as possible.
- Approach 2: Equip convective parameterizations with more functionalities (via triggering/closure) so that they can offer immediate reliefs in certain aspects.
- Either way, conventional parameterizations are important for synthesizing and advancing our understanding.

2. Processes/Models: ML-based Convective Parameterizations

- At ~3-km, GSRMs show a lot of promises in explicitly resolving deep convection, and convective-large scale interactions.
- That said, model divergences and sensitivity to other parameterizations persist. More tuning in the weather forecast mode is needed.
- The ML-trained convective heating/moistening rates, when implemented in coarse-resolution models, do a good job in mimicking more expensive CSRMs.
- More development and analysis are needed.

3. Phenomena/observations: Organized convection (MCS, convective-large scale interactions)

- Ground- and space-based radars, and field measurements offer detailed depictions of MCS.
- That said, there is no unifying theory for explaining many characteristics of MCS (such as life cycle).
- Attempts are made to make connections between observations and models, for example in terms of convective vs. large-scale precipitation. But caveats remain. May perform phenomena based model evaluation.
- Other ways are suggested:
  - Nudged model simulations and realistically initialized hindcasts allow for comparisons on the synoptic scale (e.g. SOCRATES).
  - Process-level model diagnostics (ongoing efforts at NOAA and DOE).
  - Coupled data assimilation.
  - Hierarchical modeling.
  - Targeted field campaign observations of MCS lifecycle and associated processes alongside model/assimilation experiments

4. What about shallow convection, PBL and microphysics (aerosols)?

- Challenging, but not hopeless.
- The sub-grid processes operate primarily locally, and interact with large-scale dynamics mainly through deep convection (clouds/radiation/SST being the other route).
- Process-level models (LES, DNS, cloud parcel models with bin microphysics, etc.) can provide guidance on developing parameterizations.
- Besides conventional parameterizations (e.g. CLUBB and EDMF), one should think hard about building ML-based emulators of process-level models, akin to what is being done for GSRMs.

Concluding thought: how to realize the synergy between weather and climate?

- Increasing computing power blurs the line between weather and climate modeling.
- The same set of fast physical processes operate at both weather and climate scales.
- Societal needs demand more accurate forecasts, and actionable information on how extreme weather events may change in a different climate.
- Multiple pathways exist to bridge the gap [ML-based parameterizations, common diagnostic framework and metrics, running climate models in the weather forecast mode or CAPT (seamless modeling approach), observational validations/constraints, etc.].
- The key is to identify a few key areas where one can make rapid progress to build up “machinery,” and more important, learn each other’s language. Precipitation in general, and MCS in particular could be a good starting point.
- Special thanks to Bryce Harrop for taking detailed notes.